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Effects of Seeding Date and Density on Yield and Agronomic Traits of Millet: A Case Study of Wangu 098 Variety of Millet

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Abstract [**Objectives**] To find out a suitable cultivation technique of Wangu 098 in Nanyang area, speed up the popularization, demonstration and application of Wangu 098, and provide a theoretical and practical basis for adjusting the planting structure and realizing the matching of improved varieties and methods. [**Methods**] The new self-bred millet variety Wangu 098 was used as the material, and the two-factor split zone experimental design was adopted. The effects of different sowing dates and densities on the yield, growth period and agronomic characters of millet were studied. [**Results**] The interaction of seeding date and density had a great effect on the yield and plant traits of millet. Millet yield was significantly and positively correlated with plant height, panicle length, single panicle weight, panicle grain weight and tiller number. [**Conclusions**] The reasonable combination of seeding date and density could give full play to the yield potential of millet. According to the experimental results and cultivation experience, the suitable seeding date of millet in Nanyang area is in the first and middle ten days of June, and the best density is about 750 000 plants/ha. However, after June 30, the seeding millet did not tiller, so the density should be increased to more than 900 000 plants/ha to obtain higher yield. In terms of cultivation and management, timely seeding, reasonable close planting, and coordination of vegetative growth and reproductive growth can make the plant tall and strong, panicle long and thick, and improve the yield of millet.

Key words Wangu 098 millet, Seeding date, Density, Agronomic traits, Yield

1 Introduction

Wangu 098 is a new millet variety with high yield, good quality and multi-resistance, and it was bred by Nanyang Academy of Agricultural Sciences. Its growth period is 88 d. The leaf sheath of the seedling is green, and the leaf attitude is semi-erect; the seedling is of less tillering type; the anther is white, the bristle is green, and the length of the bristle is moderate; the plant height is 123.45 cm, and the panicle length is 19.99 cm. The spike is fusiform, and spike density is moderate. The spike weight per plant is 16.38 g, the spike grain weight is 13.39 g, 1 000-grain weight is 2.64 g, and grains are yellow. The hulless grain texture is non-glutinous. Crude protein content is 11.30%, crude fat content is 3.10%, total starch content is 62.00%, amylopectin content is 52.64%, and lysine content is 0.25%. It is millet blast moderate resistant, millet leaf rust resistant, millet downy mildew moderate resistant, nomatode moderate resistant, and the stem borer rate is 0.40%. Wangu 098 has been registered by the Ministry of Agriculture and Rural Affairs with the registration number GPD Millet (2022) 410136.

In order to find out a suitable cultivation technique of Wangu 098 in Nanyang area, speed up the popularization, demonstration and application of Wangu 098, and provide a theoretical and practical basis for adjusting the planting structure and realizing the matching of improved varieties and methods[1-2], we performed an experiment to study the effects of seeding date and density on the main agronomic traits and yield of Wangu 098.

2 Materials and methods

2.1 Overview of the experimental site The experiment was carried out in the experimental base of Liaohe Town, Nanyang Academy of Agricultural Sciences in 2022. The experimental base is a plain dry land with an altitude of 120 m, and the soil type is black clay[3]. The previous crop was cotton, and the average temperature during the millet growth period from June to September was 28.9, 28.2, 28.5 and 23.7 ℃, respectively, which was 3, 0.8, 2.1 and 1.7 ℃ higher than that in normal years. The accumulative precipitation during the growing period of millet from June to September was 52, 139.2, 99.6 and 4.2 mm, respectively, which was 67.8, 42.2, 28.6 and 74.0 mm less than that of the same period in previous years.

2.2 Experimental materials and design The experimental variety was Wangu 098 millet. Table 1 gives the details of the two-factor split-plot experimental design, and Table gives the details of 20 treatments and 3 times of repetition, and the plot area is 12 m^2.

2.3 Item recording and methods The morphological characteristics, growth and development dynamics of millet were observed and recorded during the growth period of millet. Before harvest, 10 representative millet plants were taken from each treatment to measure the plant height, and 10 representative ears were taken for indoor seed examination.

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Table 1 Experimental factors and levels

Level	Seeding date//Month-day (Factor A)	Level	Density//10^4 plant/ha (Factor B)
1	June 2	1	45
2	June 9	2	60
3	June 16	3	75
4	June 23	4	90
5	June 30		

2.4 Data analysis Excel 2007 and SPSS 20.0 were used for data processing and analysis.

3 Results and analysis

3.1 Effect of weather on agronomic traits During the growing period of millet in Nanyang area in 2022, the temperature from June to September was higher than the annual average temperature, and the rainfall was less than that in the same period of previous years, especially the average temperature in June was 28.9 ℃, which was 3 ℃ higher than that in normal years; the rainfall from June to July was 52.0 and 139.2 mm, respectively, which was 67.8 and 42.2 mm less than that in the same period of previous years. It can be seen from Table 3 that the high temperature and rainless weather from June to July in 2022 led to the reduction of plant height, single panicle weight and panicle grain weight of several treatments of A2.

Table 2 Treatment level for seeding date and density experiments

Treatment	Seeding date//Month-Day	Density//10^4 plant/ha
A1B1	June 2	45
A1B2	June 2	60
A1B3	June 2	75
A1B4	June 2	90
A2B1	June 9	45
A2B2	June 9	60
A2B3	June 9	75
A2B4	June 9	90
A3B1	June 16	45
A3B2	June 16	60
A3B3	June 16	75
A3B4	June 16	90
A4B1	June 23	45
A4B2	June 23	60
A4B3	June 23	75
A4B4	June 23	90
A5B1	June 30	45
A5B2	June 30	60
A5B3	June 30	75
A5B4	June 30	90

Table 3 Main agronomic traits and yield performance of millet with different seeding date and different density

Seeding date	Density	Plant height cm	Panicle length cm	Panicle thickness//mm	Single Panicle weight//g	Panicle grain weight//g	1 000-grain weight//g	Tiller number pcs/100 plants	Yield kg/ha
A1	B1	137.0 a	18.9 a	21.39 a	16.2 a	12.4 a	3.02 a	94.7 a	4 835 a
	B2	134.6 a	16.8 a	21.23 a	15.1 b	10.9 b	2.66 b	73.0 b	4 752 a
	B3	147.0 a	19.0 a	20.16 a	14.8 b	11.4 b	2.64 b	69.0 b	5 084 a
	B4	142.3 a	17.8 a	19.90 a	15.1 b	10.8 b	2.55 b	50.3 c	5 002 a
A2	B1	120.7 a	17.6 a	18.06 b	15.8 a	13.7 a	2.75 a	51.0 a	4 584 bc
	B2	120.7 a	18.1 a	19.80 a	14.5 b	12.6 b	2.54 ab	35.7 b	5 002 ab
	B3	117.8 a	17.2 a	16.93 b	13.6 b	11.3 c	2.48 b	22.0 c	5 334 a
	B4	113.7 a	15.6 a	20.25 a	13.6 b	11.5 c	2.61 ab	21.3 c	4 251 c
A3	B1	133.4 a	17.2 ab	19.76 ab	16.9 a	13.9 a	2.53 b	60.0 a	4 362 b
	B2	137.4 a	17.7 ab	20.55 a	14.4 c	11.8 b	2.80 a	53.3 b	5 000 ab
	B3	135.0 a	16.1 b	19.91 a	15.6 b	13.4 a	2.63 ab	24.0 c	5 352 a
	B4	133.9 a	18.9 a	17.75 b	13.3 c	11.5 b	2.40 b	25.7 c	4 584 ab
A4	B1	121.8 a	18.0 a	22.24 a	13.6 a	11.2 a	2.60 a	34.3 a	1 949 b
	B2	114.0 a	16.7 a	18.52 b	10.2 b	8.0 b	2.75 a	14.0 c	2 504 ab
	B3	119.4 a	17.8 a	20.14 ab	12.7 a	10.6 a	2.55 a	18.0 b	2 779 a
	B4	114.1 a	16.1 a	19.02 b	9.1 c	7.5 b	2.64 a	11.3 d	2 173 ab
A5	B1	110.9 a	14.5 a	20.12 b	11.9 a	9.5 a	2.59 ab	0 a	1 396 b
	B2	113.0 a	15.3 a	20.05 b	10.3 b	7.4 c	2.55 bc	0 a	1 337 b
	B3	111.2 a	15.0 a	24.28 a	11.8 a	9.4 ab	2.44 c	0 a	1 527 b
	B4	111.8 a	14.5 a	18.48 b	11.5 ab	8.6 b	2.68 a	0 a	2 857 a

NOTE Different lowercase letters after each column of data indicate significant differences at the 0.05 level ($P<0.05$).

3.2 Effect of seeding date and density on yield It can be seen from Table 3 that the yield of several treatments of A1 was high, and there was no significant difference among the treatments, and the yield of A1B3 was the highest; the yield of several treatments of A2 was higher, and there were significant differences among the treatments. Among them, the yield of A2B3 and A2B2 was higher. The yield of A3 was also higher, and there were significant differences among the treatments. Among them, A3B3, A3B2 and A3B4 had the highest yield. The yield of A4 and A5 treatments was significantly lower, indicating that the yield was

significantly reduced if the seeding period was too late, that is, the earlier the seeding, the better. The suitable seeding date was in the first and middle ten days of June, and the yield decreased by more than 50.9% after the last ten days of June. For early seeding, density has little effect on yield. In the suitable seeding date, the yield was the highest when the density was 750 000 plants/ha, and the density should be increased if the seeding date was too late.

3.3 Effect of seeding date and density on growth period It can be seen from Table 4 that the seeding date has a greater impact on the growth period of millet. When the seeding date is the same, the density has no impact on the growth period of millet. Treatments A1, A2, A3, A4, and A5 experienced 5, 4, 3, 3, and 3 d from seeding to emergence, respectively. This is because the temperature rises gradually from the first ten days to the last ten days of June, if the seeding is early, the temperature is low and the emergence is slow; if the seeding is late, the temperature is high and the emergence is fast. The number of days elapsed from emergence to heading decreases as the seeding date is delayed. Among them, A5 treatment lasted the shortest (33 d), which was 7 d less than A1 treatment. When seeding time is early, the vegetative growth of millet is long and vigorous; when seeding time is too late, millet blast is serious in seedling stage, which is not conducive to vegetative growth and reproductive growth, and the maturity is poor.

Table 4 Effect of seeding date and density on the growth period of Wangu 098

Seeding date	Density	Seeding to emergence	Emergence to heading	Heading to maturity	Growth period//d
A1	B1	5	40	46	86
A1	B2	5	40	46	86
A1	B3	5	40	46	86
A1	B4	5	40	46	86
A2	B1	4	39	43	82
A2	B2	4	39	43	82
A2	B3	4	39	43	82
A2	B4	4	39	43	82
A3	B1	3	36	42	78
A3	B2	3	36	42	78
A3	B3	3	36	42	78
A3	B4	3	36	42	78
A4	B1	3	34	49	83
A4	B2	3	34	49	83
A4	B3	3	34	49	83
A4	B4	3	34	49	83
A5	B1	3	33	46	79
A5	B2	3	33	46	79
A5	B3	3	33	46	79
A5	B4	3	33	46	79

3.4 Effect of seeding date and density on main agronomic traits The yield and main agronomic traits of millet under different seeding dates and densities are shown in Table 3.

3.4.1 Plant height. The plant height was greatly affected by the seeding period. There was no significant difference in plant height among treatments A1, A2, A3, A4 and A5, but there was significant difference among treatments with different seeding dates. The plant height decreased gradually (except that seeding date of A2 was greatly affected by the weather); the plant height was not significantly affected by the density, and there was no significant difference in the plant height during the same seeding period.

3.4.2 Panicle length. The panicle length was not significantly affected by the seeding date. There was no significant difference in panicle length among A1, A2, A3 and A4 treatments, but the panicle length of A5 treatment with the latest seeding date was significantly shorter. The panicle length was not significantly affected by density, and there was no significant difference in panicle length among B1, B2, B3 and B4 treatments.

3.4.3 Panicle thickness. The panicle thickness was not significantly affected by the seeding date. There was no significant difference in panicle thickness among A1, A3, A4 and A5 treatments, and A2 treatment was less affected by weather. The panicle thickness was not significantly affected by seeding density, and there was no significant difference in panicle thickness among B1, B2 and B3 treatments, but the panicle thickness of B4 with the highest seeding density was smaller.

3.4.4 Single panicle weight. The single panicle weigh was greatly influenced by the seeding date. There were significant differences among treatments A1, A2, A3, A4 and A5. In addition, A1, A2 and A3 had higher single panicle weight, that is, if the seeding date was early, single panicle weight was high; if the seeding date was too late, the single panicle weight was high and was obviously reduced. The single panicle weight was also affected by the density, and there were significant differences among B1, B2, B3 and B4 treatments. The single panicle weight was high when the density was low, and the single panicle weight was low when the density was high.

3.4.5 Panicle grain weight. Panicle grain weight was greatly affected by seeding date. There were significant differences among treatments A1, A2, A3, A4 and A5. The panicle grain weight of treatments A1, A2, A3, A4 and A5 were the highest, that is, if the seeding date was early, the panicle grain weight was higher. If the seeding date was too late, the panicle grain weight was significantly reduced. The panicle grain weight was also affected by the density, and there were significant differences among treatments B1, B2, B3 and B4. When the density was low, the panicle grain weight was high, and when the density was high, the panicle grain weight was low.

3.4.6 The 1 000-grain weight. The 1 000-grain weight is greatly affected by seeding date. There were significant differences among treatments A1, A2, A3, A4 and A5. The 1 000-grain weight was also greatly affected by density, and there were significant differences among treatments B1, B2, B3 and B4. The 1 000-grain weight was high when the density was low, and it was low when the density was high.

3.4.7 Tillering. Tillering was greatly affected by seeding date. There were significant differences among treatments A1, A2, A3, A4 and A5, and Treatment A5 had no tiller. Specifically, the ear-

lier the seeding date, the more the tillers, and the later the seeding date, the less the tillers. Especially, when the seeding date was June 30, there was no tiller. The tillering was also affected by the density, and there were significant differences among treatments B1, B2, B3 and B4. The smaller the density, the more tillers, and the higher the density, the less tillers.

3.5 Correlation between yield and main agronomic traits It can be seen from Table 5 that the yield was significantly positively correlated with plant height, panicle length, single panicle weight, panicle grain weight and tiller number. The yield was not significantly positively correlated with the 1 000-grain weight, but negatively correlated with the panicle thickness. The correlation was single panicle weight > panicle grain weight > plant height > tiller number > panicle length > 1 000-grain weight.

Table 5 Correlation of different seeding date and density with main agronomic traits and yield

Traits	Plant height	Panicle length	Panicle thickness	Single panicle weight	Single panicle grain weight	1 000-grain weight	Tiller number	Yield
Plant height	1							
Panicle length	0.707**	1						
Panicle thickness	0.054	−0.115	1					
Single panicle weight	0.721**	0.555*	0.082	1				
Single panicle grain weight	0.568**	0.546*	−0.025	0.934**	1			
1 000-grain weight	0.217	0.177	0.067	0.209	0.109	1		
Tiller number	0.807**	0.724*	0.129	0.795**	0.636**	0.523*	1	
Yield	0.726**	0.603**	−0.320	0.778**	0.751**	0.180	0.683**	1

NOTE * denotes significant correlation at the 0.05 level and ** means extremely significant correlation at the 0.01 level.

4 Conclusions and discussion

The effects of seeding date and density on yield, growth period and agronomic traits of Wangu 098 were studied by a two-factor split-plot design. The results showed that seeding date had significant effects on plant height, single panicle weight, panicle grain weight, tiller number and yield. Density also had great effects on single panicle weight, panicle grain weight, tiller number and yield of millet. Therefore, the interaction between seeding date and density has a greater impact on the yield and plant traits of millet, and the results are the same as those of Fan Huiping and Li Yongquan[4]. The yield of millet increased first and then decreased with the increase of planting density, and the result was similar to the findings of Liu Haiping[5-6]. Millet yield was significantly and positively correlated with plant height, panicle length, single panicle weight, panicle grain weight and tiller number[7]. In order to make the plant tall and strong, panicle long and thick, to play the yield potential of a single plant and improve the yield of millet under the protection of population advantage, we should carry out timely seeding, rational close planting and coordinate vegetative and reproductive growth in cultivation and management. Therefore, the reasonable combination of seeding date and density can give full play to the yield potential of millet. According to the experimental results and cultivation experience, the suitable seeding date of millet in Nanyang area is in the first and middle ten days of June, and the best density is about 750 000 plants/ha, but there is no tillering after June 30, so the density should be increased to more than 900 000 plants/ha to obtain higher yield.

References

[1] FAN HP, GUO EH, WANG XQ, *et al.* Effects of sowing time and plant density on main agronomic characters and yield of millet variety Changnong No. 35[J]. Journal of Hebei Agricultural Sciences, 2010, 14(11): 13-14,34. (in Chinese).

[2] LI QX, LI ZH, GUO EH, *et al.* Effects of different sowing period, density and fertilization amount on yield and agronomic traits of Changnong 39 [J]. Journal of Anhui Agricultural Sciences, 2016, 44(12): 41-43, 46. (in Chinese).

[3] NIU YT, JU L, CHEN PY, *et al.* Adaptability analysis of 29 new millet varieties in Nanyang basin[J]. Shaanxi Journal of Agricultural Sciences, 2023, 69(7): 31-37, 47. (in Chinese).

[4] LI YQ, ZHAO YY, SUN XL, *et al.* Adaptability evaluation of agronomic traits and nutrient quality of millet in northern Shanxi province[J]. Journal of Shanxi Agricultural Sciences, 2023, 51(6): 645-652. (in Chinese).

[5] LIU HX, WANG SJ, SONG ZQ, *et al.* Study on different planting densities of Yugu 18[J]. Bulletin of Agricultural Science and Technology, 2018(9): 115-117. (in Chinese).

[6] ZHANG X. Study on selection of drought-tolerant millet varieties and cultivation techniques in northern Shaanxi[D]. Yangling: Northwest A&F University, 2017. (in Chinese).

[7] NIU YT, QIANG XJ, CHEN PY, *et al.* Effects of different sowing time on yield and agronomic traits of millet in Nanyang area[J]. Barley and Cereal Sciences, 2019, 36(4): 23-25. (in Chinese).